Jurnal Teknik Sipil
Volume. 2 No. 1 June 2024
p- ISSN: 3021-8713 ,e- ISSN: 3021-8705 hal 01-16
DOI: https://doi.org/10.59581/sipil.v2i1.87

Analysis of the Application of Hollow Core Slab to Cost and Time Efficiency in High Rise Building Construction Project

Fanny Ardiana Harijanto[1*], I Nyoman Dita Pahang Putra[2], Nia Dwi Puspitasari[3]
[1,2,3]Faculty Of Engineering And Science, Pembangunan Nasional "Veteran" of University East Java
Email: [1]fanny1ardiana@gmail.com, [2]putra.indp.ts@upnjatim.ac.id, [3]nia.dwi.ts@upnjatim.ac.id
Author corresponding: fanny1ardiana@gmail.com

***Abstract**: The floor slab is one of the factors that affect the cost and duration of construction projects because it has the largest volume of work among other jobs. The selection of the method of implementation of floor slab work also affects the efficiency of development. The use of precast slabs can be an alternative to conventional floor slabs because of their potential to increase cost efficiency, speed up implementation time, and increase structural durability. In this study, a comparative analysis of cost efficiency and scheduling time of precast hollow core slab (HCS) method as an alternative to conventional slabs was conducted, using primary data obtained from the project and in accordance with government regulations. Time analysis and scheduling were calculated with the help of Microsoft Project software and determination of plate work items. As for the cost analysis, it is calculated based on the literature and applicable regulations to get real results by field conditions. Based on the analysis, it is known that the implementation of the 4-storey building slab work with the alternative precast slab method takes 8 days and costs IDR 1,691,887,497. While the conventional slab method takes 38 days with a total cost of ID. 2,276,920,601.*

***Keywords**: hollow core slab, work items, time scheduling, and cost*

BACKGROUND

Building construction in Indonesia has grown rapidly and continues to innovate, fueling the demands of short-term construction driven by efforts to improve efficiency, sustainability, and cost-effectiveness. The choice of slab work implementation method has a key role in determining the time and cost of a construction project because it consumes a large amount of material (Romadhoni & Sahid, 2023). hollow core slabs can be an alternative to conventional slabs in terms of improving cost efficiency, accelerating construction time, and structural durability (Propika et al., 2023).

The use of hollow core slabs does not require formwork or scaffolding during implementation, so the duration of construction time is shorter (Pajriah & Rijaluddin, 2022). Currently, the application of hollow core slabs in Indonesia is still limited, although it has been widely applied in developed countries. Therefore, it is necessary to conduct a study for in-depth understanding so as to optimise the implementation of hollow core slab in Indonesia.

This research aims to conduct a comparative analysis of the cost efficiency and project schedule of the application of hollow core slabs and conventional slabs in building construction with respect to volume calculations and load calculations on floor slabs. According to Widanti, Wijayaningtyas, and Indra (2020), the integration of the use of precast slabs is expected to increase the efficiency of building construction, reduce construction waste, bring significant

Received April 30, 2024; Revised May 31, 2024; Accepted June 31, 2024
*Fanny Ardiana, fanny1ardiana@gmail.com

benefits, and provide evidence regarding the cost and time efficiency of its use in Indonesia so that it can be considered for application in future projects..

THEORETICAL REVIEW

A. Slab

A slab is a rigid planar structure that does not lie directly on the ground, acting as a barrier between one level and another (Putri et al., 2023). There are several methods in floor slab work, such as the conventional method, bondek method, precast method, and precast half slab method. This research discusses two methods of floor slab work, namely conventional floor slabs and hollow core slabs-type precast floor slabs.

B. Conventional Slab

According to Nauly, Rambe, and patriotika (2022), the conventional method of plate is made of reinforced concrete material with a certain thickness, which is done at the direct casting site, with multiplex wood as formwork and scaffolding as a scaffold to support the plate formwork. This method is the traditional method and is most widely used in construction projects, but it requires a long time to process.

C. Hollow Core Slab

Hollow core slab is a variation of precast plates that has a cavity or hole in the centre of the plate with the aim of reducing the volume and self-weight of the plate without reducing the flexural strength of the plate (Naser et al., 2021). Hollow core slabs is moulded with high-quality concrete and high-quality steel using special moulds and prestressed steel using a prestressed prestressing system before the components are unloaded from the mould (Tusadiyah & Sukobar, 2022).

In determining the type and size of hollow core slab plates, loading calculations are carried out by reviewing the dead load and live load planned based on SNI 1727-2020. Hollow core slab self-weight is usually determined by the manufacturer. Hollow core slab plates are declared capable of use if they fulfil the formula.

$$Qn \geq qu$$

Note : Qn = Hollow core slabs capacity (kg/m^2)

Qu = the ultimate load received by conventional plates (kg/m^2)

D. Cost Analysis

Cost analysis is a cost evaluation and assessment process that aims to determine and control costs, as well as help allocate resources and management strategies (Riyadi et al., 2022). The cost analysis calculation is carried out based on the unit price of work (HSPK), which will then produce a cost budget plan. The formula for calculating cost budget plan is as follows :

Cost budget plan = ∑volume of work × unit price of work

E. Time Analysis

Time analysis in development projects is an effort to analyse how long it takes to complete all work items (Pertiwi et al., 2023). The result of the time analysis is a work plan in the form of a work implementation schedule. Time analysis is calculated using the formula :

Number of Worker = work volume × work coefficient

Productivity = $\frac{number\ of\ worker}{work\ coefficient}$

Duration = $\frac{work\ volume}{work\ productivity}$

RESEARCH METHOD

In order to achieve the objectives of this research, the following steps were taken: :

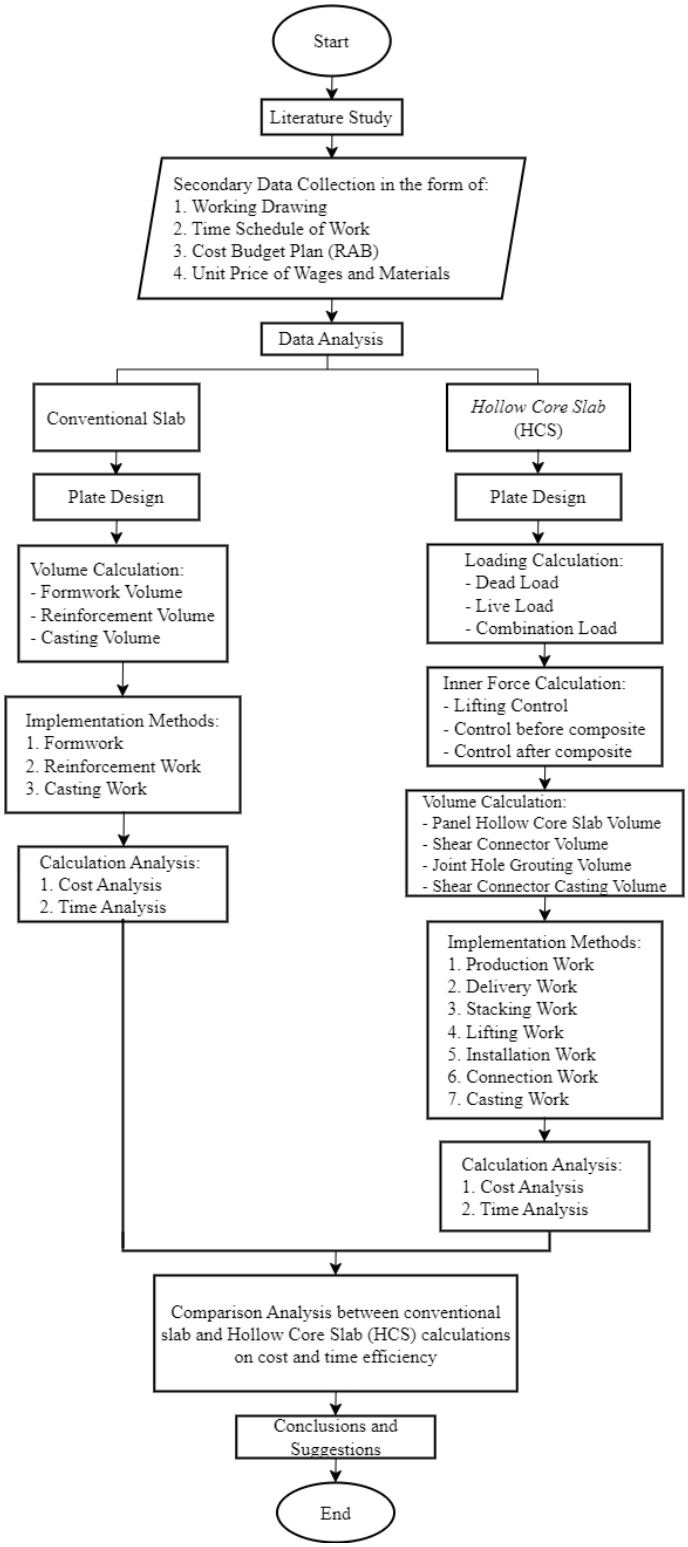

Figure 1. Flowchart of the Research

Source: project documents

This research uses secondary data to process data to compare the results of cost and time analysis of conventional and hollow core slab methods. The conventional slab uses data obtained from the project, while the hollow core slab is planned to use a precast plate owned by PT Beton Elemenindo Perkasa (BEP) with a size profile of 150.05.12

RESULT AND DISCUSSION

A. Plate Design

1. Conventional Slab

The conventional method of plate design in this study uses the real conditions in the construction project field, namely using Ø12-150 reinforcement, 13 cm plate thickness, and concrete quality f'c 30 mpa (k-350).

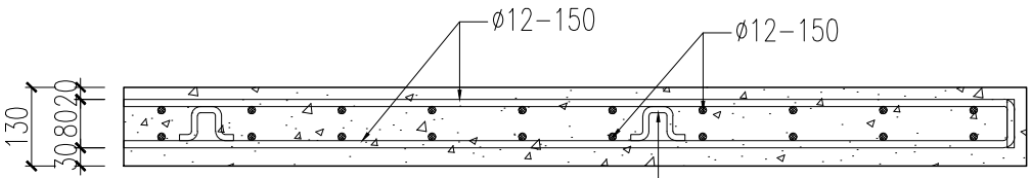

Figure 2. Conventional Slab Detail

Source: project documents (2024)

2. Hollow Core Slab

The alternative design in this study uses hollow core slab plate specifications from the company PT Beton Elemenindo Perkasa (BEP) with a maximum bearing capacity (net, after deducting its own weight) of 665 kg/m2 for hollow core slab plates with a thickness of 150 mm, a PC wire diameter of 5 mm, and a number of tendons of 12, the longest span of 4.5m. It is necessary to perform loading calculations on the three conditions of the hollow core slab to determine the dimensions of the precast slab to be used.

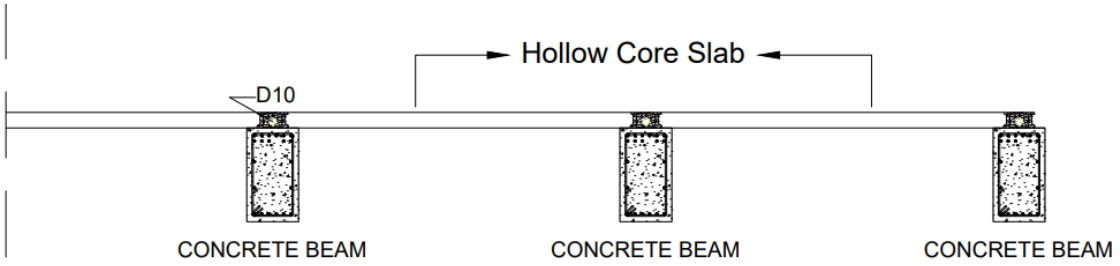

Figure 3. Hollow Core Slab Slab Detail

Source: project documents (2024)

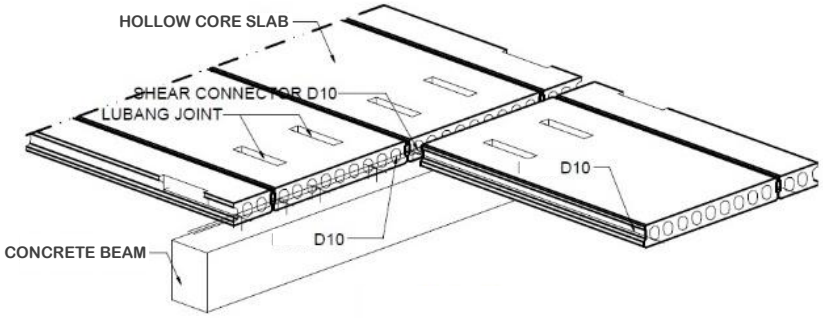

Figure 4. Hollow Core Slab Slab Instalation Details

Source: project documents (2024)

In the condition after composite, the calculated loads are hollow core slab self load obtained from Hollow core slabs brochure, dead load based on SNI 1727-2020 table c3.1-1 and table c3.1-2, and live load planned for school building based on SNI 1727-2020 table 4.3-1. In the pre-composite condition, the calculated load is the hollow core slabs self-weight and temporary construction load (worker load), and in the lifting condition, the calculated load is the self-weight of the hollow core slab.

- Before composite condition

  Dead Load (DL) =247 kg/m^2

  Live Load (LL) = 100 kg/m^2

  Ultimate Load (Qu) = 456,4 kg/m^2

- Lifting condition

  Dead Load (DL) =247 kg/m2

  Ultimate Load (Qu) = 345,8 kg/m^2

- Composite condition

  Dead Load (DL) =113,3 kg/m2

  Live Load (LL) = 306,4 kg/m2

  Ultimate Load (Qu) = 626,2 kg/m^2

Referring to the PCI design manual for hollow core slab plates and loading combinations in accordance with SNI 2847:2019 regulations, hollow core slab plates can be used if the hollow core slabs bearing capacity (Qn) is greater than the ultimate load (Qu).

- Before composite condition

  Qn ≥ Qu

  665 kg/m^2 ≥ 456,4 kg/m^2 **(OK!)**

- Lifting condition

  Qn ≥ Qu

  665 kg/m^2 ≥ 345,8 kg/m^2 **(OK!)**

- Composite condition

  Qn ≥ Qu

  665 kg/m^2 ≥ 626,2 kg/m^2 **(OK!)**

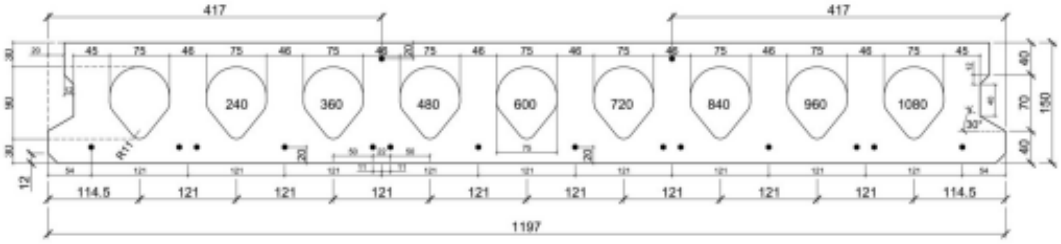

Figure 5. Hollow Core Slab Slab Detail

Source: project documents (2024)

In addition to the ultimate load (Qu) and bearing capacity of the hollow core slab (Qn), control calculations are also performed to ensure the strength of the hollow core slab to be used. The controls include moment capacity control, shear control, and crack capacity control in three conditions, namely the condition before composite, the condition after composite, and the condition when the hollow core slab is lifted. The results of the control calculations in the three conditions all meet the requirements in accordance with SNI 2847: 2019. Thus, it can be concluded that the hollow core plate with profile 150.05.12 with the longest span of 4.5 meters is able to withstand the planned load without experiencing structural failure.

B. Calculation of Plate Volume

According to Saragi & Zalukhu (2022), the calculation of the volume of work is used as the basis for calculating costs; the amount of work volume is determined based on the plan drawings of each work item. The calculation of the volume of conventional plate work consists of formwork, reinforcement work, and casting work. The volume of conventional slab work is obtained from project documents based on working drawings, so it is not calculated again. The results of the recapitulation of the volume of conventional plates can be seen in the following table:

Table 1. Conventional Plate Type and Size

No	Type of work	Volume	Unit
First Floor (Elv. -0.050)			
1	Ready mix concrete fc' = 30 Mpa; K-350	133,21	m^3
2	Formwork	28341,9	kg
3	Lightweight Brick Formwork	204,94	m^2
4	Working Floor Concrete fc' = 8.3 Mpa; K-100 tbl = 5 cm	51,23	m^3
5	Sand	51,23	m^3
Second Floor (Elv. +4.450)			
1	Ready mix concrete fc' = 30 Mpa; K-350	128,73	m^3
2	Reinforcement	27389,31	kg
3	Formwork	198,05	m^2
Third Floor (Elv. +7.950)			
1	Ready mix concrete fc' = 30 Mpa; K-350	128,73	m^3
2	Reinforcement	27389,31	kg
3	Formwork	198,05	m^2
Fourth Floor (Elv. +13.450)			
1	Ready mix concrete fc' = 30 Mpa; K-350	128,73	m^3
2	Reinforcement	27389,31	kg
3	Formwork	198,05	m^2

Source: project documents (2024)

In the hollow core slab plate work, the calculation of hollow core slab panel work, shear connector connection work, hollow core slab joint point grouting work, and hollow core slab plate casting work The hollow core slab plate is planned to have a thickness of 150 mm, a maximum width of 1.2 m, and a maximum length of 4.5 m (adjusted for field size). The results of the hollow core slab volume recapitulation can be seen in the following table.

Table 2. Recapitulation of Hollow Core Slab Plate Volume Calculation

No	Volume	Unit	Volume
First Floor (Elv. -0.050)			
1	Number of hollow core slab panels	pcs	343
2	Hollow core slab panel volume	m3	103,420
3	Shear Connector Requirement	kg	422,73

No	Volume	Unit	Volume
4	Joint hole grouting	m3	1,98
5	Joint casting D10 reinforcement	m3	17,17
Second Floor (Elv. +4.450)			
1	Number of hollow core slab panels	pcs	333
2	Hollow core slab panel volume	m3	99,905
3	Shear Connector Requirement	kg	410,41
4	Joint hole grouting	m3	1,92
5	Joint casting D10 reinforcement	m3	16,99
Third Floor (Elv. +7.950)			
1	Number of hollow core slab panels	pcs	333
2	Hollow core slab panel volume	m3	99,905
3	Shear Connector Requirement	kg	410,406
4	Joint hole grouting	m3	1,918
5	Joint casting D10 reinforcement	m3	16,992
Fourth Floor (Elv. +13.450)			
1	Number of hollow core slab panels	pcs	333
2	Hollow core slab panel volume	m3	99,905
3	Shear Connector Requirement	kg	410,406
4	Joint hole grouting	m3	1,918
5	Joint casting D10 reinforcement	m3	16,992

Source: Processed by Researcher (2024)

C. Work Items

The determination of work items is carried out to facilitate the process of calculating time and cost in accordance with the implementation stage carried out in order to obtain optimal results. The existing condition of the slab in the construction project is using the conventional method, and in this research, it is planned to change the conventional slab to an hollow core precast slab.

The work items of the conventional slab method and hollow core slab method in this study are as follows :

1. Conventional slab

   a) formwork

b) Reinforcement work

c) Casting work

2. Hollow Core Slab

a) Moving and lifting work

b) Installation work

c) Connection work

d) Casting work

D. Time and Cost Analysis of Plate Work

From the results of volume calculations, calculations can be made to determine the duration of work and the total cost of work. The calculation of work duration and scheduling is carried out with the help of Microsoft Project software, while the calculation of costs is obtained from the product of work duration and the unit price of work.

1. Time Analysis

The calculation of conventional plate time analysis uses the productivity value obtained from the project's unit price analysis. A recapitulation of the calculation of the duration of each conventional method of slab work can be seen in Table 3.

Table 3. Recapitulation of Conventional Plate Duration

Type of work	Duration (Day)
First Floor (Elv. -0.050)	
Sand	1
Working Floor Concrete fc' = 8,3 Mpa; K-100 tbl = 5 cm	1
Reinforcement	5
Lightweight Brick Formwork	1
Ready Mix Concrete fc' = 30 Mpa; K-350	
Second Floor (Elv. +4.450)	
Formwork	4
Reinforcement	5
Ready Mix Concrete fc' = 30 Mpa; K-350	1
Third Floor (Elv. +7.950)	
Formwork	4
Reinforcement	5
Ready Mix Concrete fc' = 30 Mpa; K-350	1

Type of work	Duration (Day)
Fourth Floor (Elv. +13.450)	
Formwork	4
Reinforcement	5
Ready Mix Concrete fc' = 30 Mpa; K-350	1

Source: Processed by Researcher (2024)

The duration of the work that has been known is followed by calculations with Microsoft Project to determine the total duration of the work, so it is known that the conventional slab method work can be completed for 38 days.

Time analysis of the hollow core slab method plate is carried out approach from AHSP PUPR Ministerial Regulation No. 1 of 2022 and PUPR Ministerial Regulation No. 28 of 2016 to find productivity, thus obtaining the total duration of each job. A recapitulation of the calculation of the duration of each hollow core slab method slab work can be seen in Table 4.

Table 4. Hollow Core Slab Plate Work Duration Recapitulation

Type of Work	Duration (Days)
First Floor (Elv. -0.050)	
Shunting Work 1 precast panel plate	1
Erection work of 1 precast panel plate	1
1 kg reinforcement work	1
1 joint grouting work on precast concrete	1
1 m3 Ready-mixed concrete (k-350) poured	1
Second Floor (Elv. +4.450)	
Shunting Work 1 precast panel plate	1
Erection work of 1 precast panel plate	1
1 kg reinforcement work	1
1 joint grouting work on precast concrete	1
1 m3 Ready-mixed concrete (k-350) poured	1
Third Floor (Elv. +7.950)	
Shunting Work 1 precast panel plate	1
Erection work of 1 precast panel plate	1
1 kg reinforcement work	1
1 joint grouting work on precast concrete	1

Type of Work	Duration (Days)
1 m3 Ready-mixed concrete (k-350) poured	1
Fourth Floor (Elv. +13.450)	
Shunting Work 1 precast panel plate	1
Erection work of 1 precast panel plate	1
1 kg reinforcement work	1
1 joint grouting work on precast concrete	1
1 m3 Ready-mixed concrete (k-350) poured	1

Source: Processed by Researchers (2024)

Further calculations were carried out with the help of Microsoft Project, knowing that the hollow core slabs work could be completed in 8 days.

2. Cost Analysis

The calculation of conventional slab cost analysis uses the unit price of work obtained from the project cost budget plan. Table 5 shows a recapitulation of the total cost required to complete the slab using the conventional method.

Table 5. Total Plate Cost Conventional Method

No	Type of Work	Total Cost
First Floor (Elv. -0.050)		
1	Ready Mix Concrete fc' = 30 Mpa; K-350	IDR 142.311.240,23
2	Reinforcement	IDR 385.676.575,20
3	Lightweight Brick Formwork	IDR 28.459.556,69
4	Concrete Work Floor fc' = 8,3 Mpa; K-100 tbl = 5 cm	IDR 45.582.022,67
5	Sand	IDR 11.941.713,00
Second Floor (Elv. +4.450)		
1	Ready Mix Concrete fc' = 30 Mpa; K-350	IDR 137.525.155,43
2	Reinforcement	IDR 372.713.730,48
3	Formwork	IDR 44.077.611,90
Third Floor (Elv. +7.950)		
1	Ready Mix Concrete fc' = 30 Mpa; K-350	IDR 137.525.155,43
2	Reinforcement	IDR 372.713.730,48
3	Formwork	IDR 44.077.611,90
Fourth Floor (Elv. +13.450)		
1	Ready Mix Concrete fc' = 30 Mpa; K-350	IDR 137.525.155,43

No	Type of Work	Total Cost
2	Reinforcement	IDR 372.713.730,48
3	Formwork	IDR 44.077.611,90
Total Cost of Conventional Plate Work		IDR. 2.276.920.601,19

Source: Processed by Researcher (2024)

Calculation of cost analysis of hollow core slab using HSPK 2022 Surabaya City approach and hollow core slab brochure owned by PT. Beton Elemenindo Perkasa (BEP) for the price of 1 hollow core slab panel. Table 6 shows the total cost required to complete the slab work using the hollow core slab method for a 4-story building.

Table 6. Total Cost of Hollow Core Slab

No	Type of Work	Total Cost
First Floor (Elv. -0.050)		
1	1 Panel hollow core slab	IDR 150.920.000,00
2	Shunting 1 hollow core slab	IDR 54.373.397,75
3	Erection 1 plate	IDR 203.119.381,43
4	Installation of plain / threaded iron	IDR 5.763.782,61
5	Casting of Ready Mixed concrete (k-350)	IDR 18.150.932,09
6	Grouting of precast joints	IDR 152.458,62
Second Floor (Elv. +4.450)		
1	1 panel hollow core slab	IDR 146.520.000,00
2	Shunting 1 hollow core slab	IDR 52.788.167,49
3	Erection 1 plate	IDR 197.197.533,57
4	Installation of plain / threaded iron	IDR 5.595.742,30
5	Casting of Ready Mixed concrete (k-350)	IDR 17.548.612,89
6	Grouting of precast joints	IDR 152.458,62
Third Floor (Elv. +7.950)		
1	1 panel hollow core slab	IDR 146.520.000,00
2	Shunting 1 hollow core slab	IDR 52.788.167,49
3	Erection 1 plate	IDR 197.197.533,57
4	Installation of plain / threaded iron	IDR 5.595.742,30
5	Casting of Ready Mixed concrete (k-350)	IDR 17.548.612,89
6	Grouting of precast joints	IDR 152.458,62

No	Type of Work	Total Cost
Fourth Floor (Elv. +13.450)		
1	1 panel hollow core slab	IDR 146.520.000
2	Shunting 1 hollow core slab	IDR 52.788.167
3	Erection 1 plate	IDR 197.197.534
4	Installation of plain / threaded iron	IDR 5.595.742
5	Casting of Ready Mixed concrete (k-350)	IDR 17.548.613
6	Grouting of precast joints	IDR 152.459
Total Cost of Hollow Core Slab		**IDR 1.691.887.497**

Source: Processed by Researcher (2024)

3. Cost And Time Comparative Analysis

The results of time and cost analysis comparative between the conventional slab method and the hollow core slab method showed in the following table 7:

Table 7. Recapitulation Of Time And Cost Comparative Analysis

Slab Methode	Time Analysis (Days)	Cost Analysis (IDR)
Conventional slab	38	IDR 2.276.920.601,19
Hollow Core Slab	8	IDR 1.691.887.497,12
Comparative defference	**30**	**IDR 585.033.104,07**

Source: Processed by Researcher (2024)

CONCLUSIONS AND SUGGESTIONS

Based on the analysis results, the comparison between the conventional slab method and the hollow core slab method showed significant differences in terms of implementation time and cost. The conventional slab method took 38 days, while the hollow core slab method only required 8 days. In addition, the cost of implementing the slab work with the conventional method reached IDR. 2,276,920,601.19, while the hollow core slab only cost IDR. 1,691,887,497.12. The use of the hollow core slab method also resulted in significant time efficiency, which was 30 days faster, and reduced costs by 26% compared to the conventional method.

However, to ensure structural reliability and durability, a more detailed follow-up study is required to evaluate the strength and durability of the hollow core slab joints. In addition, in order to select the optimal construction method, it is necessary to conduct a thorough

comparative analysis with precast construction methods, including columns, beams, and slabs. This approach will provide a more comprehensive picture and enable better decision-making in the planning and implementation of the construction project in question.

REFERENCES

Naser, F. H., Mamoori, A. H. N. Al, & Dhahir, M. K. (2021). Effect of using different types of reinforcement on the flexural behavior of ferrocement hollow core slabs embedding PVC pipes. *Ain Shams Engineering Journal*, *12*(1), 303–315. https://doi.org/10.1016/j.asej.2020.06.003

Nauly, A., Rambe, M. R., & Patriotika, F. (2022). Analisa Perbandingan Biaya Dan Waktu Pelaksanaan Pelat Lantai Konvensional Dengan Pelat Lantai Pracetak Pada Gedung Berlantai Tiga. *Statika*, *5*(2), 55–62. https://jurnal.ugn.ac.id/index.php/statika/article/view/1071

Pajriah, D. N., & Rijaluddin, A. (2022). Pelaksanaan Pekerjaan Plat Lantai Dengan Beton Precast Pada Proyek Penataan Ggm Tahap 1. *Seminar Teknologi Majalengka (Stima)*, *6*, 239–249. https://doi.org/10.31949/stima.v6i0.709

Pertiwi, W. S. D. M., Wijayaningtyas, M., & Iskandar, T. (2023). Analisis Percepatan Proyek dengan Metode Crashing Program pada Proyek Pembangunan Gedung Rumah Sakit Islam Unisma Malang. *Student Journal Gelagar*, *5*(1), 47–56.

Propika, J., Septiarsilia, Y., Susanti, E., & Pertiwi, D. (2023). Komparasi Sistem Pelat Konvensional dan Sistem Pelat Precast Hollow Core Slab pada Struktur Gedung. *Jurnal Teknologi Dan Manajemen*, *4*(2), 111–118. https://doi.org/10.31284/j.jtm.2023.v4i2.4491

Putri, P. F. C., Putra, I. N. D. P., Nauli, A. R., & Kamandang, Z. R. (2023). Analisa Produktivitas Dan Biaya Penggunaan Struktur Komposit Dan Konvensional Pelat Lantai Pada Proyek Pembangunan Tahap Ii Rsud Dr. M. Soewandhie Surabaya. *Jurnal Ilmiah MITSU (Media Informasi Teknik Sipil Universitas Wiraraja)*, *11*(1), 73–82. https://doi.org/10.24929/ft.v11i1.2075

Riyadi, I., Handayani, E., & Dony, W. (2022). Analisa Perbandingan Sistem Pelat Konvensional dengan Sistem Precast Half Slab dalam Segi Waktu dan Biaya. *Jurnal Civronlit Unbari*, *7*(2), 63. https://doi.org/10.33087/civronlit.v7i2.100

Romadhoni, M., & Sahid, M. N. (2023). *JURMATEKS Efektivitas Metode Pekerjaan Pelat Lantai Bondek , Half Precast dan*. *6*. https://doi.org/10.30737/jurmateks.v6i2.4949

Saragi, T. E., & Zalukhu, N. K. (2022). Analisa Perbandingan Pelaksanaan Struktur Pelat

Lantai Metode Konvensional, Boundeck Dan Precast Full Slab Ditinjau Dari Segi Waktu Dan Biaya Pada Proyek Pembangunan Gedung Gbkp Tanah Merah Binjai. *Jurnal Teknik Sipil*, *1*(2), 38–52. https://ejournal.uhn.ac.id/index.php/construct/article/view/550

Tusadiyah, S. Y., & Sukobar, S. (2022). Analisis Biaya dan Waktu Pelaksanaan Metode Alternatif Hollow Core Slab pada Gedung Apartemen Surabaya. *Jurnal Teknik ITS*, *11*(3). https://doi.org/10.12962/j23373539.v11i3.107938

Widanti, P. A., Wijayaningtyas, M., & Indra, S. (2020). *Penerapan Alternatif Metode Hollow Core Slab Pada Pembangunan Gedung Malang Creative Center*. *X*(X), 1–5. https://eprints.itn.ac.id/12025/9/JURNAL.pdf